DESIGN OF MUIS TESTER USING HYDRAULIC SYSTEM

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Abstract:

This is a project of "Design of mechanical unit injector (MUI) tester machine using hydraulic system." Mechanical unit injector is a fuel injector of a loco engine used by INDIAN Railways. It is the most important part of the fuel system which is a high-pressure fuel metering pump and spray valve combined into one compact unit. MUI tester is basically used to check the atomization and spray pattern of the fuel injector to detect any defect if present. It was a manually operated tester with lot of human effort required to give 40 strokes for one-unit testing which indeed was a hectic task for the worker to test each injector as per the designated manual. However, with the help of hydraulic system (hydraulic power pack including motor, pump, pressure gauge, etc.) this tester is converted into a semi-automated machine hence reducing human efforts. Owing to different methods of automation hydraulic system has proved to be more efficient in transmission of power along with lesser moving parts. Firstly, the calculations are done manually considering various design considerations for pressure capability and capacity of the injector to withstand the jerk during operation. Then certain dimensions of hydraulic cylinder are finalized using FESTO software and required speed is achieved. Later, 3D modeling of the entire setup is done using SOLIDWORKS software. These joint efforts have practically resulted into a working semi-automated MUI tester.

Keywords: MUI tester, fuel injector, hydraulic system, semi-automated, FESTO

1. INTRODUCTION

In the cutting-edge universe of today, power through hydraulic assumes a significant role in the everyday existences of industries. Its significance can be gauged from the way that it is viewed as one piece of the muscle that moves the business. It is achieved with the help of pressurized liquids. Fluid mechanics lays a foundation for hydraulic system design and their actuation.

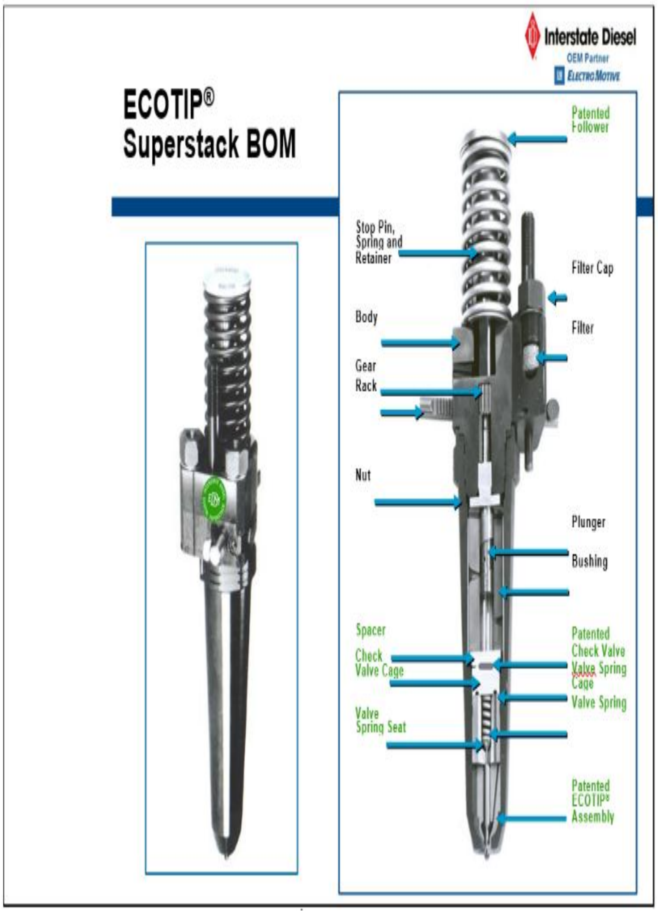

Fig - 1: Diesel Engie Fuel Injector

The fuel injector tester is a machine basically used to check the atomization and spray pattern of the fuel injector used in Diesel loco engines of Indian railways.

1.1 Holding Pressure and Leak Test

All injectors lose pressure due to leakage at any of several points, but this leakage must be controlled during injector manufacture to prevent engine lube oil dilution. The holding pressure test will qualify injectors having specified leadoff rates, providing this leakage is at the proper point and is satisfactorily control Manually hold the test stand fuel line block on the injector. Pump until fuel is discharged from filter cap on opposite side, to remove air. Tighten block securely to injector using a hex nut applied to the injector stud. Tighten to 40 in lbs (4.5 Nm) Apply 2000 psi (138 Bar) pressure to the injector. No leakage is permitted at the nut to body seal, filter cap gasket, body plugs, or between spray tip and injector nut.

Reconditioned injectors should be qualified on the pressure holding test by timing the interval for a drop in pressure from 2000 psi to 1500 psi (138 to 103 Bar). If this interval is less than 30 seconds, repeat the test, but close the pressure shutoff valve on the test stand immediately after establishing the 2000 psi (138 Bar) pressure. This is to ensure that the leak-down time is not being affected by possible leakage in the test stand itself. If the timed interval for the pressure drop from 2000 psi to 1500 psi (138 to 103 bar) is still less than 30 seconds, the injector should be rejected.

1.2 Rack Freeness Test

To relieve the pressure before removing the injector from the test stand, wrap a cloth around the injector fuel line connections and back off on the clamping wrench should be rejected The control rack engages with a small pinion on the injector plunger and serves to rotate the plunger with respect to two ports in the injector bushing, which regulates the amount of fuel injected with each stroke of the plunger. The gear, rack and upper portion of the plunger are lubricated by engine oil, not diesel fuel so a binding or sticking of the rack can be caused by carbon particle in the engine oil, damaged gear teeth (caused by excessive force on rack), scored plunger and/or bushing, or galling of rack itself. A binding rack may cause sluggish or erratic speed changes and overspeed trip action. To be considered satisfactory, the rack must fall in and out through full travel, by its own weight, when injector is held horizontally and rotated about its axis.

1.3 Binding Plunger Test

Failure of the injector plunger to move up and down freely indicates scoring of the plunger and bushing, or weak or broken spring. A binding plunger will cause erratic cylinder firing and, in extreme cases, over speed trip action. Place injector in test stand but do not attach the fuel line. Place rack in the full fuel position and pump all the fuel out of the injector with injector popping lever. When all of the fuel has been removed, depress the injector plunger to full extent of its travel. Slowly release popping lever and simultaneously move injector rack repeatedly in and out through its full travel.

A binding or stuck plunger can be caused by improperly inserting the plunger into the bushing during assembly. The plunger must be well lubricated with calibrated oil/diesel fuel and inserted into the bushing gently and without any rocking or wiggling motion, otherwise a chip can be loosened on the plunger helix edge which will cause a P&B seizure when in operation. Some common causes (but not a complete list) of a stuck/seized plunger and bushing during locomotive operation are dirty fuel, excessively hot fuel (caused by running the locomotive tanks empty or near empty), algae growth in the fuel tanks and unapproved fuel additives.

2. MULTIPLE WAYS OF ACTUATION

The machine available at the car shed at Kalyan was manually operated, which indeed was to hectic for the workers to test each injector as per the designated manual. For easier operation it was crucial for the industry to turn this manual machine into a semi-automated or completely automated machine.

Fig 2: Hydraulic Actuated Fuel Injector Testing Machine

There are multiple ways of actuation such as

- Manual
- Pneumatic
- Hydraulic
- Electromagnetic

And every method has its own pros and cons. Among all, the best suitable and considered for heavy duty usage are hydraulic systems. Also, it has lesser moving parts and better power transmission.

3. DESIGN CONSIDERATIONS

There are numerous considerations on which appropriate hydraulic cylinder is selected for a particular task. Hydraulic cylinder is normally selected considering the bore size or the OD (outer diameter) and rod diameter.

Failure in this consideration may lead to inappropriate result required for a particular task which will alter its service life and efficiency. Depending this consideration are to be followed

- Piston diameter based on column strength and required speed
- Material for constriction
- Cylinder and rod coatings
- Cylinder loading pressure
- Flow rate
- Mounting style for required application
- Material for construction

4. DESIGN CALCULATIONS

Technical specifications of mechanical unit injector

- Pump rated speed- 900rpm
- Nozzle operating pressure 234bar
- Power rating 4500 HP
- Pressure capacity 1200bar

Fig3: Technical specification (MUIS testing injector)

Based on above required specifications hydraulic pump cylinder are designed as follows-

4.1 Pump calculations

PISTON AREA

$$A == \pi d^2/4 \quad = \pi\, 0.035^2/4$$

$$= 0.000962 \text{ sq. m}$$

PRESSURE CREATED

P=F÷A =31415/0.000962 = 326555925.16Pa

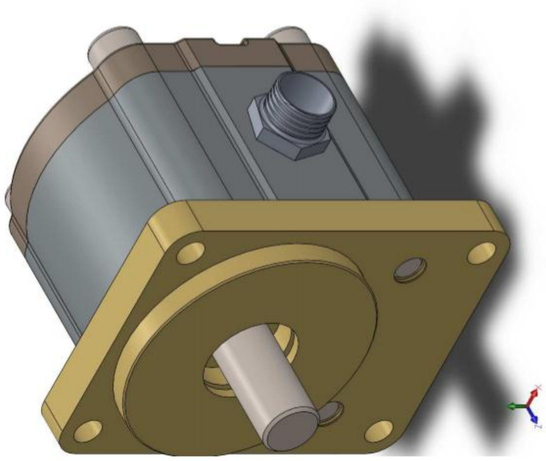

Fig 4: Hydraulic pump

- Flow rate

A] cub m/s

Q = P/p =0.00004567 cub m/s

B] LPM

Q = P/p ×60000 = 2.74 lpm

Owning to the standard pumps available selecting 4lpm pump

- Horsepower Required to Drive Pump:

GPM x PSI x .0007 (this is a 'rule-of-thumb' calculation)

GPM x PSI x .0007 = 1.05 x 3626 x .0007

= 2.75 horsepower

THUS SELECTING 2 HP MOTOR

2 = 3625 x LPM

1714 x3.78

LPM= 3.5 ~4

Output flow of 4LPM

SELECTING 4LPM PUMP CAPACITY (Flow of 4 liter/min is suitable for 0.03m/s)

Pump Displacement Needed for LPM of Output Flow:

Required pump displacement for 4lpm output flow

q=231 x LPM ÷ RPM*3.78

RPM = 1500

231 x GPM ÷ RPM = 231 x 4 ÷ 1500*3.78

= 0.1629 cub inch/ rev

4.2 Hydraulic Cylinder Calculations

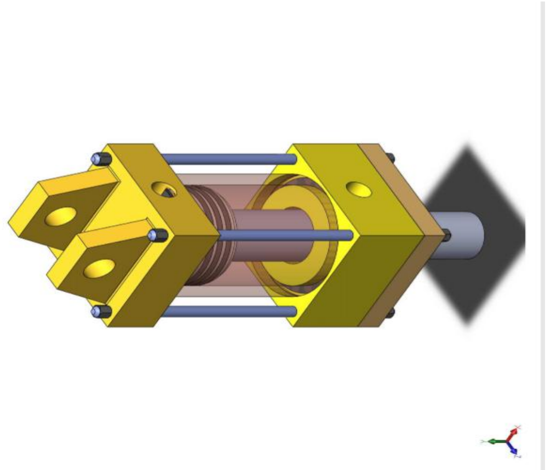

Fig 5: Hydraulic cylinder

Cylinder Blind End Area (in square inches):

Diameter =2.362 inch

AREA= π×2.362×2.362/4

=4.3795 sq. inch

Cylinder Rod End Area (in square inches):

Diameter =1.378 inch

AREA= π×1.378×1.378/4

= 1.4913 sq. inch

Net area =Blind end area – Rod end area

= 7.215-1.4913

=2.8882 sq. inch

Cylinder output force

Push force of 3.031" diameter cylinder operating at 3626 psi

$\frac{F}{A} = P$ i.e. F= 3626 ×4.3795

=15880.067pounds
=70367.759N

Pull force of a 3.031' diameter cylinder with 1.378" diameter rod

$\frac{F}{A} = P$ i.e F= 3626 ×5.7236

=10450.132pounds
=46483.916N

Speed of cylinder with 1.378 diameter rod to extend with 4lpm input

V= 231×lpm/60×A×3.78
= 231×4/60×3.78×7.215
=0.5646 inch/s

Table 1-Basic Conversions

To Convert	Into	Multiply By
Bar	PSI	14.5
cc	Cu. In.	0.06102
Kg	lbs.	2.205
KW	HP	1.341
Liters	Gallons	0.2642
mm	Inches	0.03937
Gallons	Liters	3.785
HP	KW	0.7457
Inch	mm	25.4
lbs.	Kg	0.4535
PSI	Bar	0.06896
In. of HG	PSI	0.4912

Speed at which it will retract back

V = 231×lpm/60×A [net area] ×3.78
= 231×4 /60×5.7236×3.78
=0.71inch/sec

4.3 Hydraulic Motor Calculations

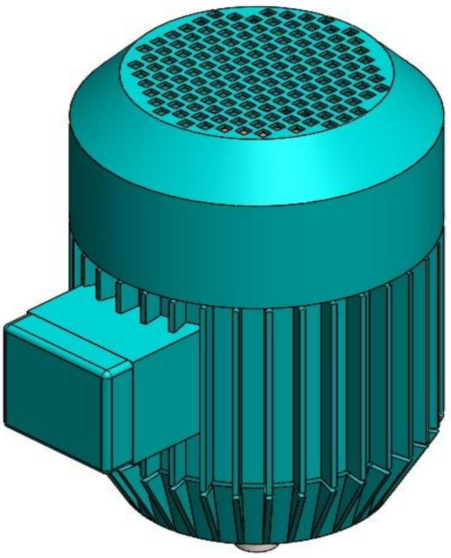

Fig 6: Motor

Angular velocity of rotor

W= 2ΠN /60

=2×3.14×1500/60

=157.07rad/sec

Required displacement

q= Q/RPM =0.004/1500

=0.00000266 cub s/rev

=0.0026 l/rev

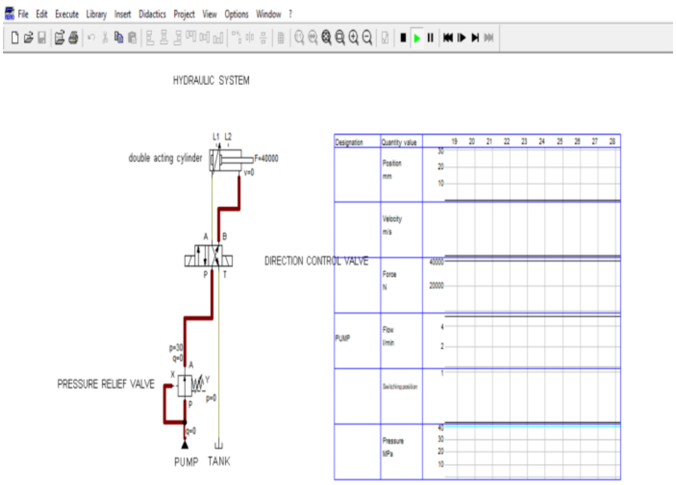

Fig 7: Hydraulic system FESTO

Fluid Motor Torque from GPM, PSI and RPM:

T=GPM x PSI x 36.77 ÷ RPM

Torque of a motor developed at 3626 psi, 1500 rpm, with 4lpm input-

LPM x PSI x 36.7 ÷ RPM

= 4x 3626 x 36.7 ÷ 1500 *3.78

= 93.87 lb. in

PUMP CAPACITY(LPM)	4lpm
HORSEPOWER	2HP
NET AREA OF CYLINDER	2.882sq. inch
PULL FORCE	70367.75N
PUSH FORCE	46483.91N
PUMP DISPLACEMENT	0.1629 cub inch/rev
SPEED OF CYLINDER	0.5646inch/sec
RETRACTING SPEED	0.71inch/sec
ANGULAR VELOSITY	157.07rad/sec
TORQUE	93.87-lb inch

5. MODEL FIGURES USING SOLIDWORKS

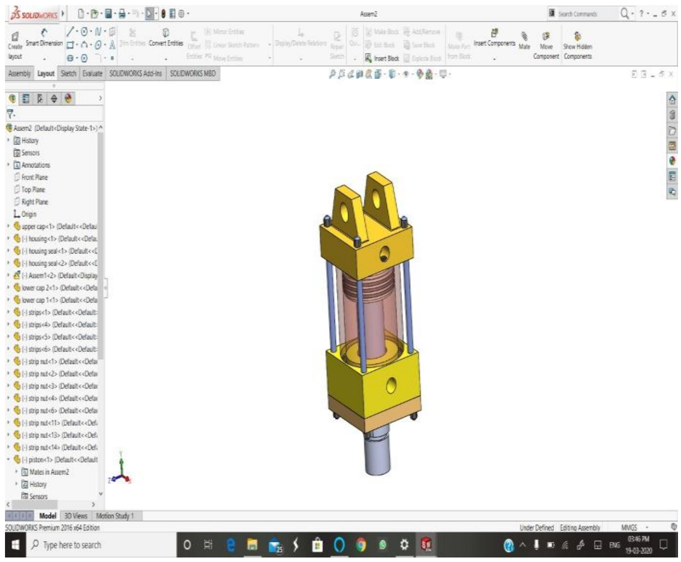

Fig 8: HYDRAULIC CYLINDER

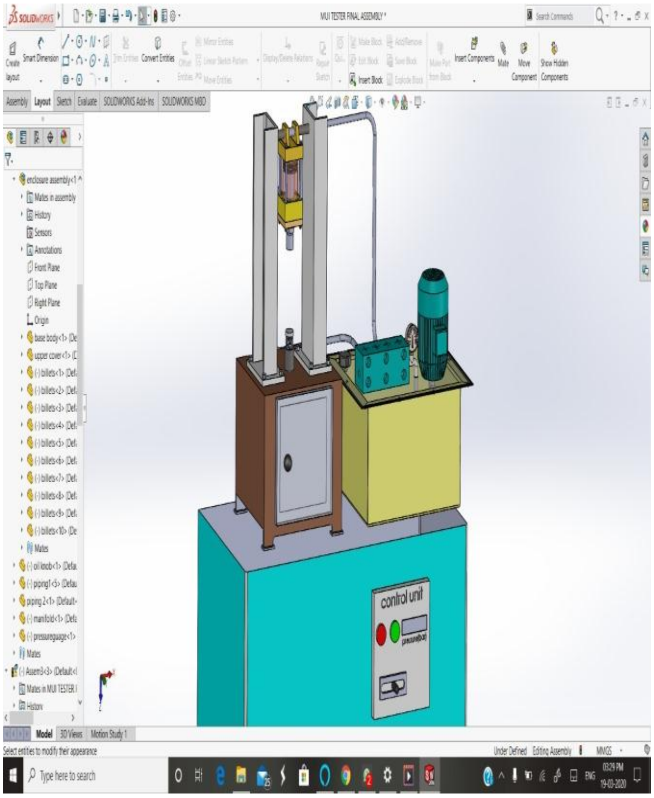

Fig 9: ASSEMBLY OF HYDRAULIC ACTUATED FUEL INJECTOR TESTOR

6. HYDRAULIC OIL

A non-compressive fluid used to transfer power within hydraulic equipment is normally synthetic or mineral based

ISO GRADE PERFORMANCE	32	68	100	150
Kinematic viscosity(40°C)	32.2	66.2	97.4	145.3
Specific gravity (15.6 °C)	0.857	0.867	0.874	0.878
Viscosity Index	115	111	107	102
Flash point °C	230	246	248	258
Color	L1.0	L2.5	L3.0	L4.5

Table 2- HYDRAULIC OIL

Here hydraulic 68 oil is preferred as it is commonly used for gear type pumps as well as vane and piston types and it functions well in lubricating light loaded reciprocating compressors. Also, hotter the temperature thinner oil becomes and vice versa, so depending on our requirement we chose stable moderate viscous ISO68 oil.

7. CONCLUSIONS

This research paper deals with focusing on hydraulic system and its working depending upon the application using appropriate conventional formulas on manual purpose and applying it getting a desire output.3D system model was generated using solid works modelling software;

Based on our application hydraulic pressure of around 230-250 bar was generated by this hydraulic unit/powerpack sustaining enough load giving accurate strokes at given time interval'

8. RESULT

The efforts of an operator have reduced drastically due to the automation of manually operated fuel injector tester. Also, the efficiency of checking has drastically improved as it delivers exact and proper force at each stroke. It also allows the operator to check each tester according to guidelines at different pressure and also provides the ability to check for the leak test.

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